

Chromate Free Magnesium Gearbox Protection System

Brad Wiley

ASETSDefense

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Outline

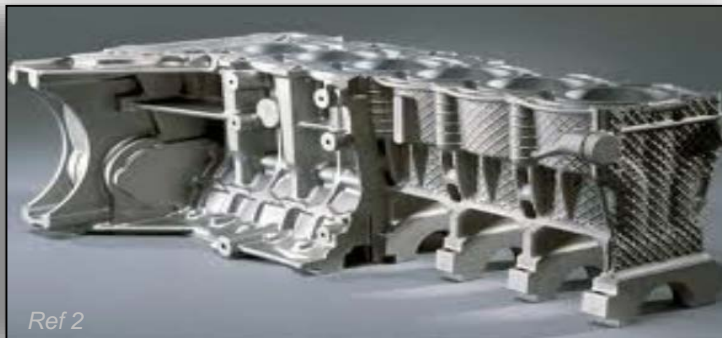
- Magnesium: Why mag?
- Application
- Challenging Feature
- Legacy System
- Candidates
- New System
- Functional Requirements, Tests and Results
- Examples of Tests
- Benefits and conclusions



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Why magnesium?

- Lightest of the structural metals
 - 1/4 of steel
 - 1/3 of aluminum
- World production: ~400,000 ann
- No limit:
 - 8th most common element
 - 6th most abundant metal
 - Sea water contains ~0.15% mag
- Recycling requires only 5% OEM
- The BMW N52 (st6 dohc engine) crankcase shell since 2004. *Ref 1*
- Since 1936, VW has used cast mag



Fast Facts: Magnesium Alloy Engine

- » Magnesium alloy engine was produced in 300,000 BMW vehicles in 2006
- » Magnesium alloy crankcase is 24 percent lighter than conventional aluminum engine
- » Engine achieves increased power output and higher torque
- » Environmental benefits are reduced fuel consumption and CO₂ emissions
- » R6 is lightest 3.0 liter inline six-cylinder gasoline engine in the world
- » Magnesium alloy engine block and bedplate with aluminum cylinder inserts
- » BMW foundry recycles 40 percent of its magnesium (9,000 tons per year)
- » R6 composite magnesium-aluminum alloy crankcase received the International Magnesium Association's Award of Excellence *Ref 2*



The R6 Composite Magnesium-Aluminum alloy engine is the mainstay of BMW's vehicle fleet.



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Why protect magnesium?

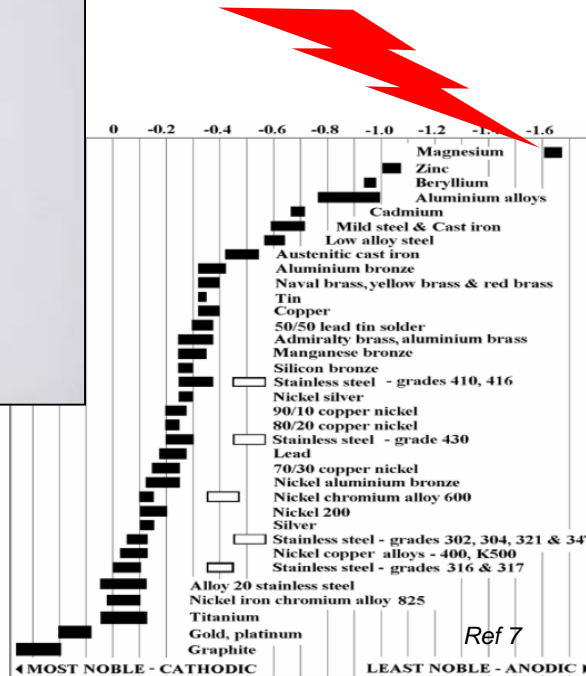
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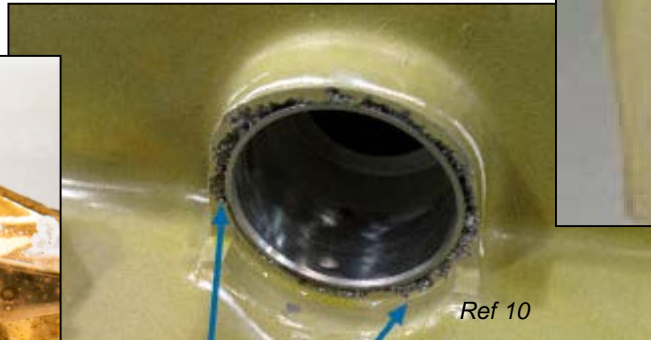
Ref 6



Ref 8



Ref 7

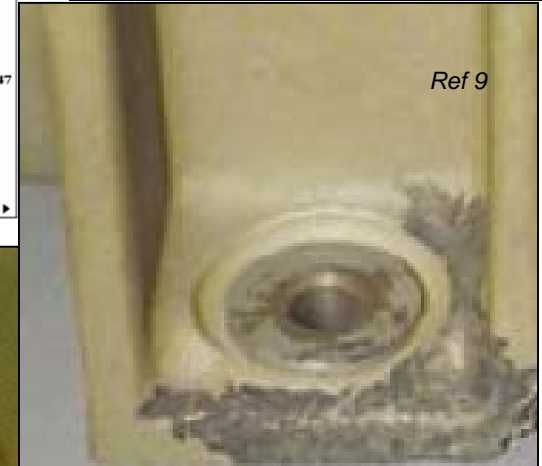


Ref 10

Ref 5

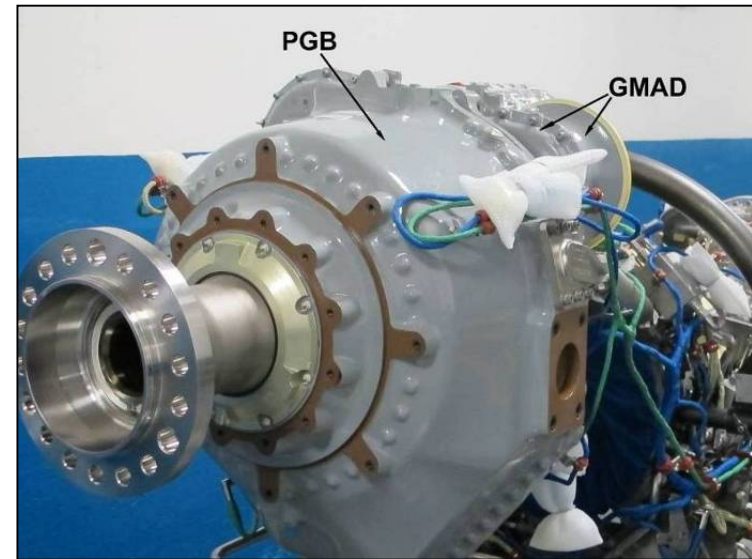


Ref 9



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The AE2100D3 engine

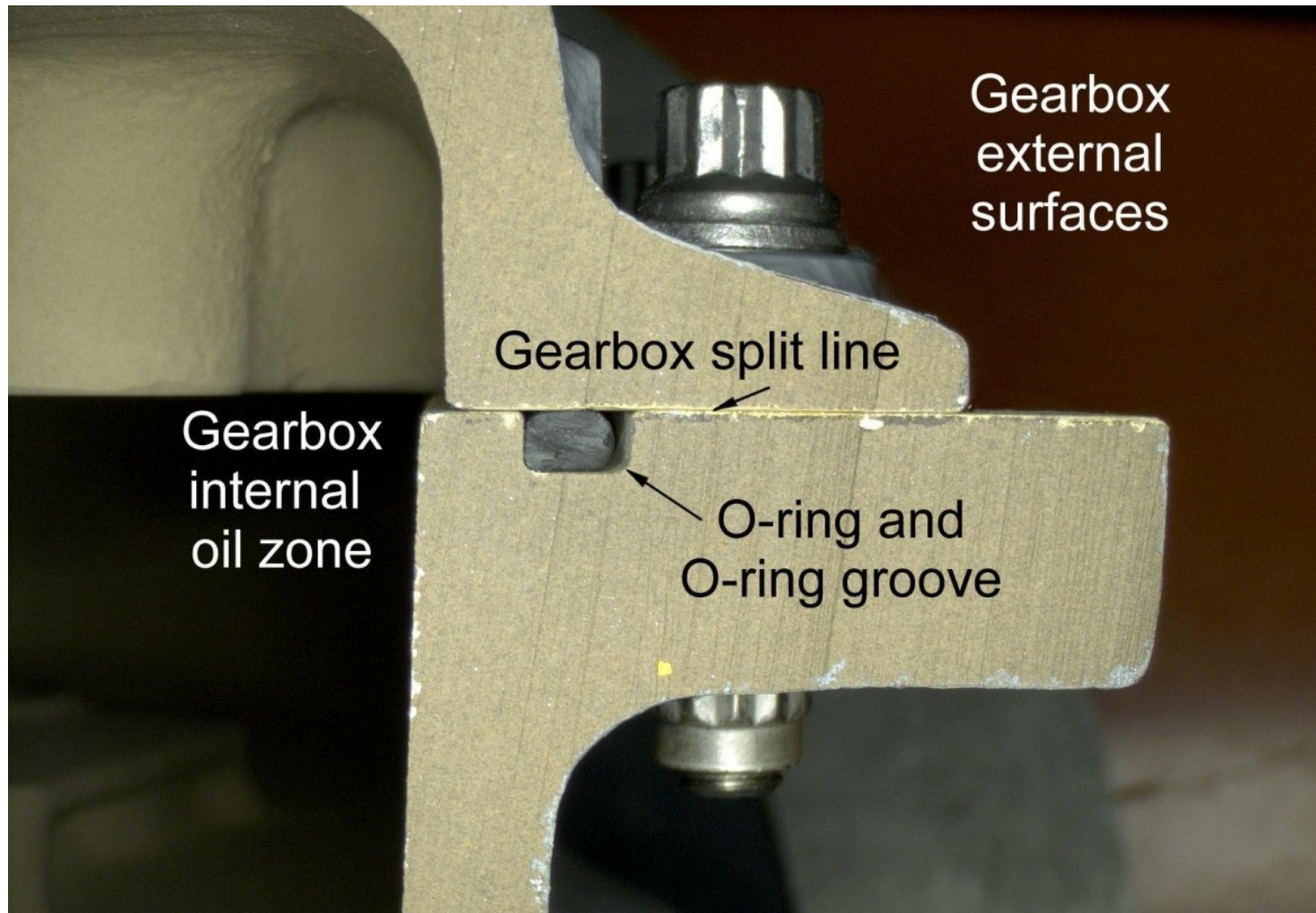


PGB – Propeller Gear Box
GMAD – Gearbox Mounted Accessory Drive



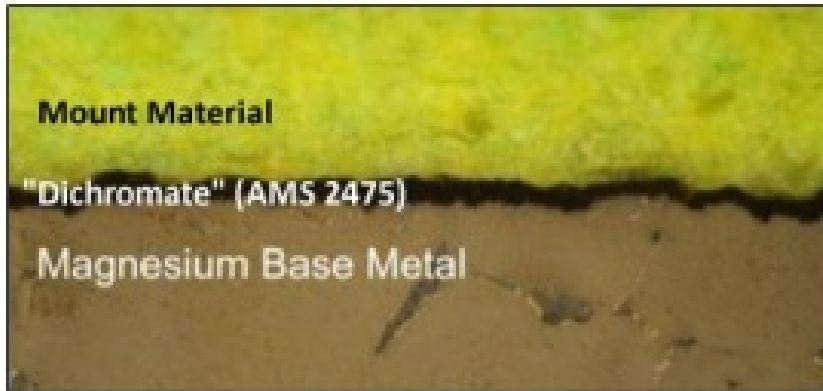
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Split line illustration



Legacy coating system

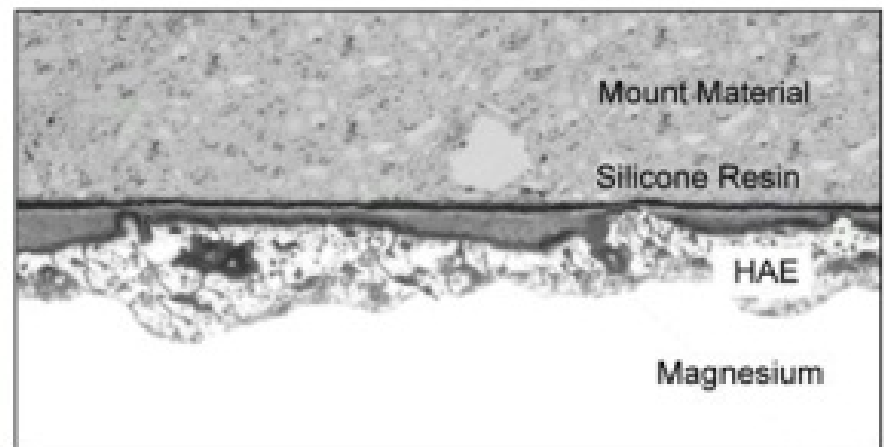
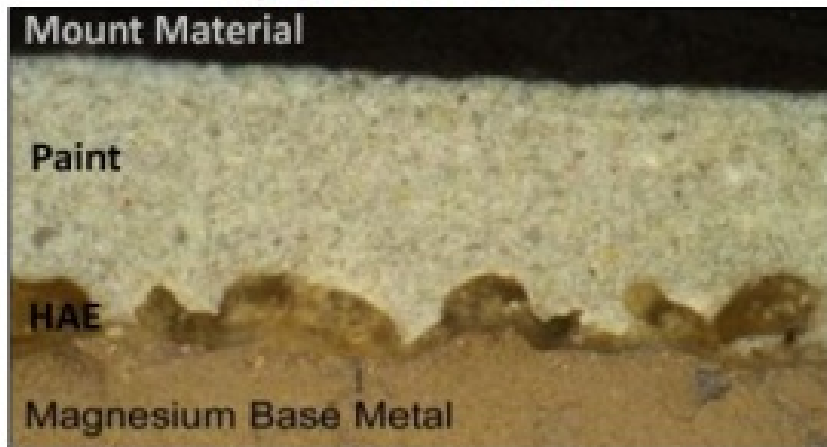
Oil Wetted Surfaces
Dichromate



Split Lines / Machined Surfaces
Silicone Resin over HAE



External Cast Surfaces
Top Coat over HAE



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Legacy coating system

- HAE
 - Patented in 1952 (by Harry A. Evangelitis)
 - Corrosion resistance
 - Surface finish
- Complex masking scheme for application
- Regulatory pressures
 - Hexavalent Cr – sustainability issue
 - High VOC content in solvents

A comprehensive replacement of the legacy coating was needed

- Improved thickness consistency
- Improved unit cost
- Lessened environmental impact
- Improved corrosion performance and aftermarket cost



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Proposed coating system

- Anodize
 - Tagnite 8200 Type 1 (AMS 2466)
- Paint
 - Indestructible Paint Ltd
 - Chromate free Low VOC 985 series
 - Sealer (green tinted)
 - Primer
 - Top Coat



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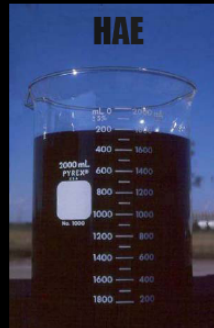
Tagnite - What is it?

TECHNOLOGY APPLICATIONS GROUP
EXCELLENCE IN MAGNESIUM SURFACE PROTECTION

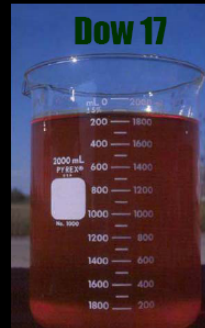
Chemical Composition as a Percentage of Water



5% * chemical concentration



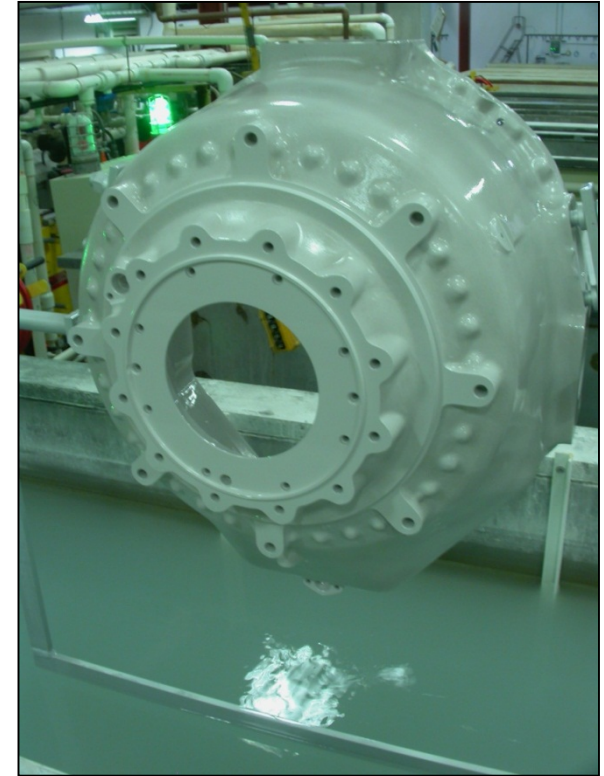
25%* chemical concentration



56% * chemical concentration

HAE contains heavy metals; Dow 17 contains heavy metals and chromium

*Approximations



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Rockhard - What is it?

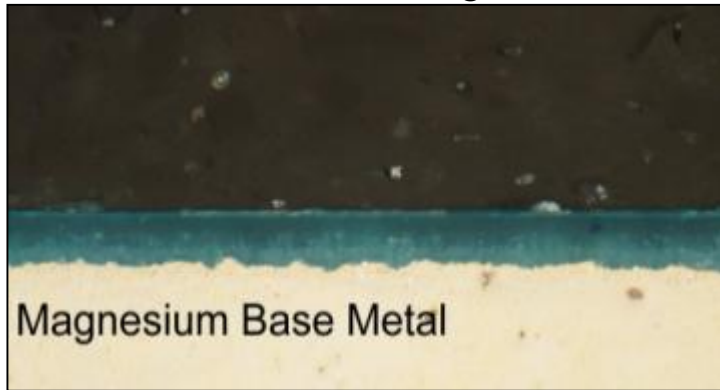


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Proposed coating system

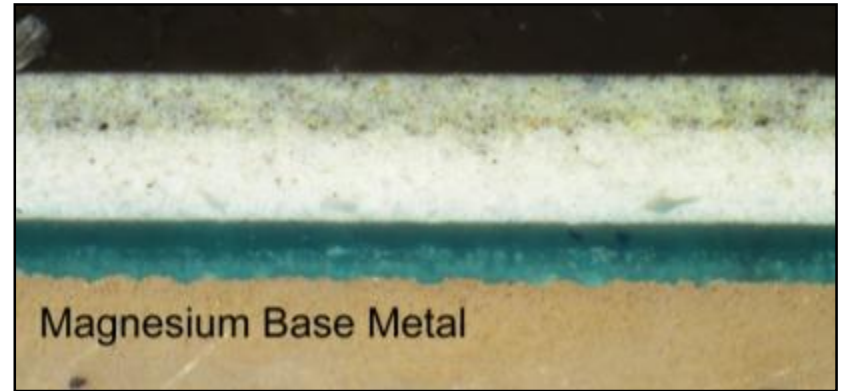
Internal Oil Wetted Surfaces

Sealer over Tagnite



Split Line /Machined Surfaces

Top Coat, Primer & Sealer over Tagnite



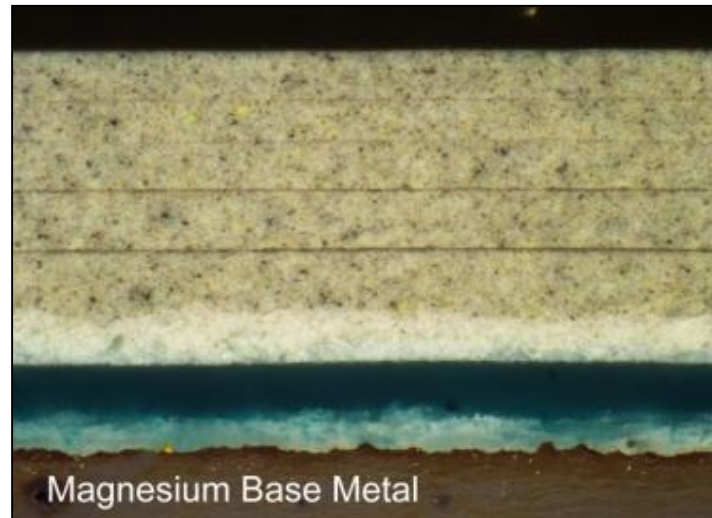
External Cast Surfaces

Top Coat, Primer & Sealer over Tagnite

Mount Material

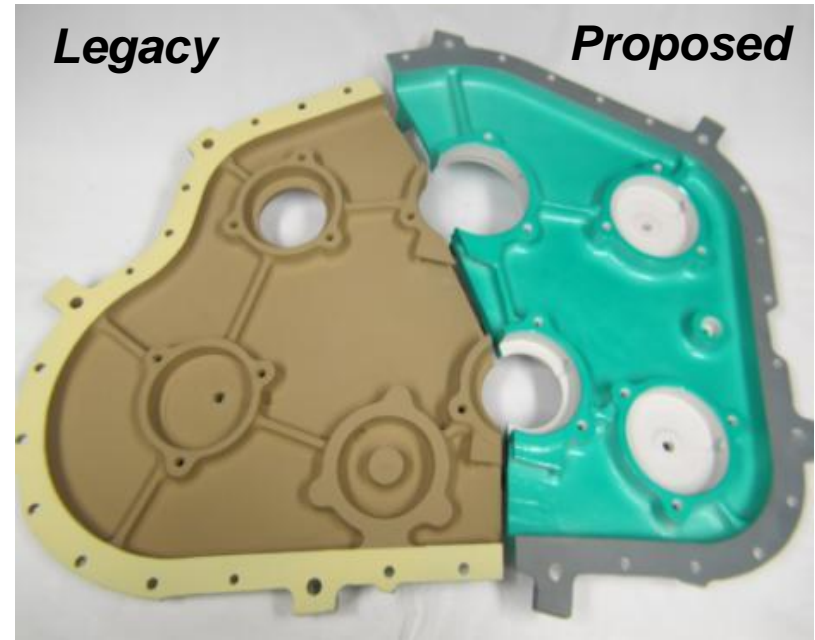
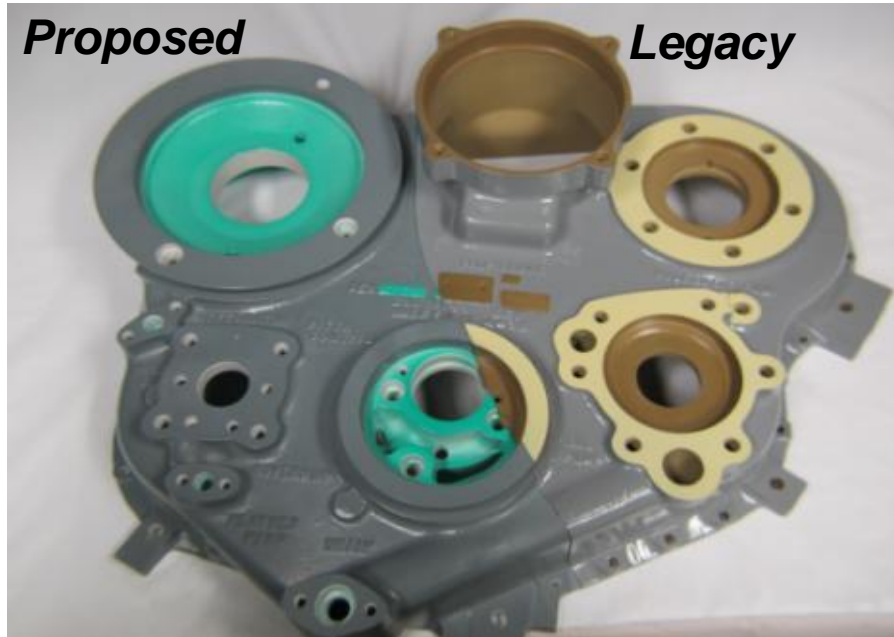
*Rockhard
Topcoat layers*

*Rockhard Primer
Rockhard Sealer
Tagnite*



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Side by side look at coating schemes



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Functional Criteria, Tests and Results

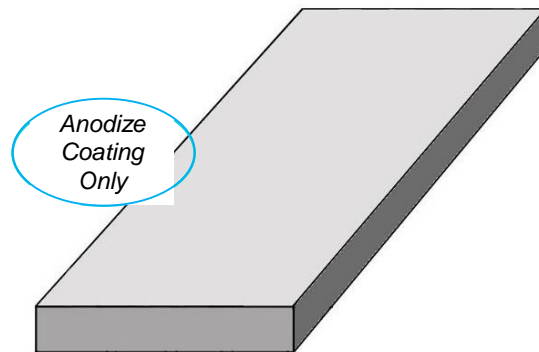
- Coating Adhesion- **PASS**
 - ASTM D3359 Method B
- Corrosion Resistance- **PASS**
 - Neutral Salt Spray: ASTM B117, ASTM D714, ASTM D1654
 - Cyclic Salt Spray:
- Thermal Stability (430°F, 1000 hrs)- **PASS**
 - ASTM D714
- Fluid Resistance (fuel, oil, hydraulic)- **PASS**
 - ISO 2812-1
- Damage Resistance (impact, bend, corner radii)- **PASS**
 - ASTM D2794, ASTM D522, Rolls-Royce Corp Test Method
- Releasability (Ease of Disassembly)- **PASS w/ use of Frekote 700-NC**
 - Rolls-Royce Corp Test Method (per IR 37340)
- Repairability (after damage and touch-up repair)- **PASS w/ Brush Tagnite**
 - Adhesion: ASTM D3359 Method B
 - Neutral Salt Spray: ASTM B117, ASTM D714, ASTM D1654
 - Metallographic
- Fatigue Testing (bar)- **PASS**
- Torque Testing (scrap part)- **PASS**
- Engine Test (assembly/leak check)- **PASS**



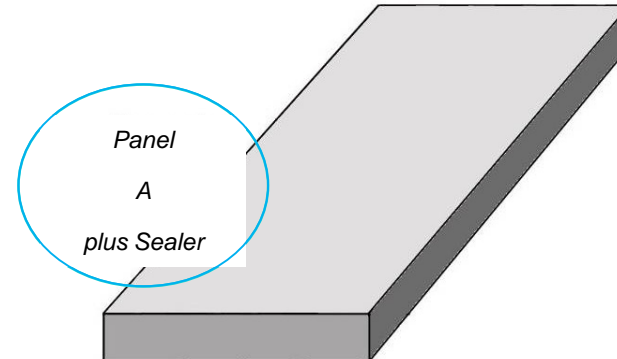
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Magnesium panels for environmental testing

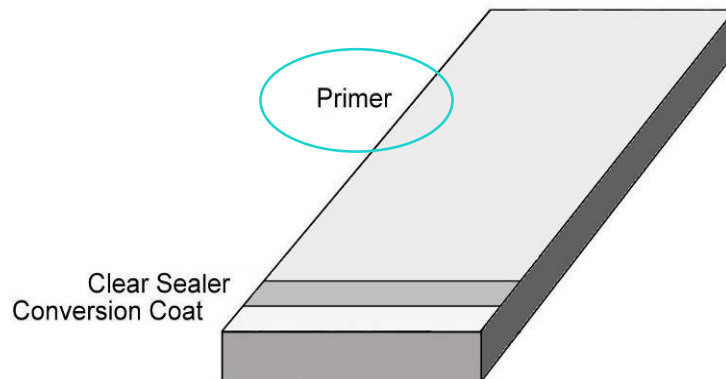
Panel Type
A



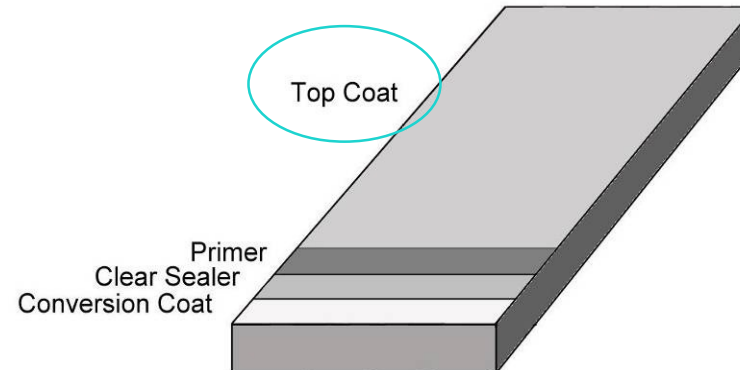
Panel Type
B



Panel Type
C



Panel Type
D



Corrosion testing – anodize coatings

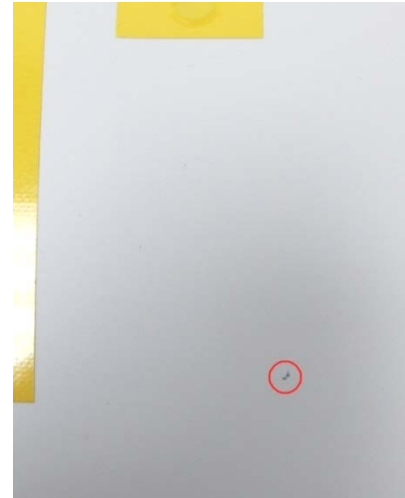
Panel Type A



HAE after 24 hrs.



Tagnite (panel 1) after 24 hrs.



Tagnite (panel 2) after 24 hrs.



HAE after 96 hrs.



Tagnite (panel 1) after 96 hrs.



Tagnite (panel 2) after 96 hrs.

Criteria: Coating shall receive a rating of 9 after exposure to 24 hours in neutral salt spray
AND
the new coating system shall meet or exceed the performance of the old coating configuration.

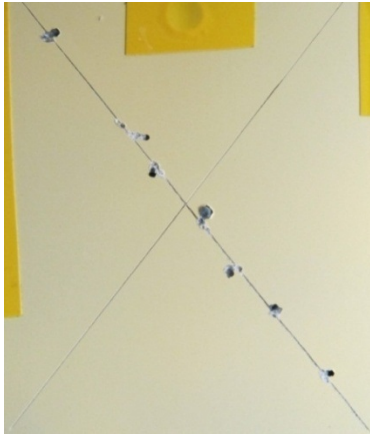
Result: Pass



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Corrosion testing – external surfaces

Panel Type C



Legacy A

Panel Type D



Legacy

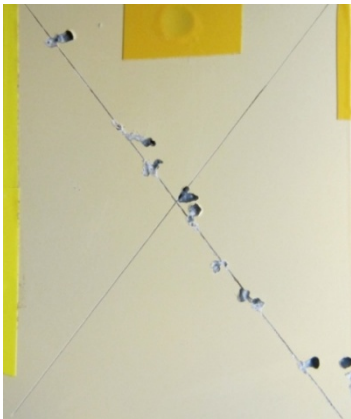
Panel Type D



New Coating

Criteria: Coating shall receive a rating of 7 after exposure to 250 hours in neutral salt spray AND the new coating system shall meet or exceed the performance of the old coating configuration.

Result: Pass



Legacy



Legacy



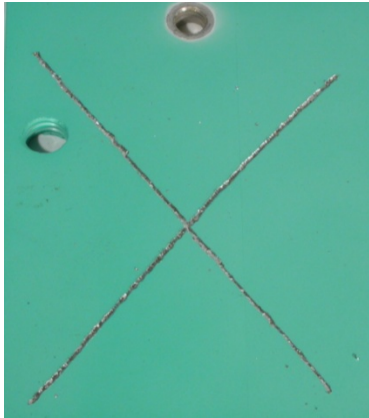
New Coating



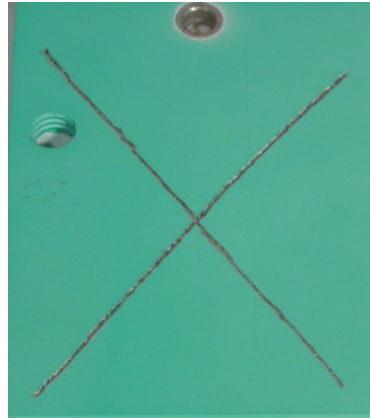
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Fluid Resistance

Rockhard Sealer- Panel Type B



Before



After

Rockhard Primer- Panel Type C

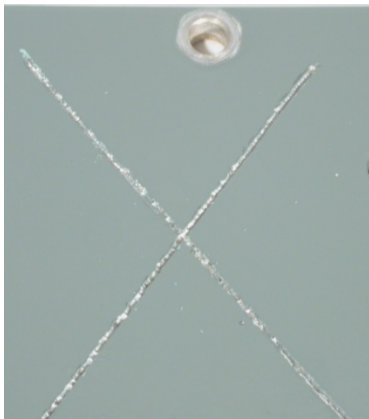


Before



After

Rockhard Top Coat- Panel Type D



Before



After

Criteria: All panels shall show no visual signs of blistering or lifting after exposure to fuel (Jet A) and hydraulic fluid (Royco 782).

Results: Pass

Fuel: 70°C, 163 hrs

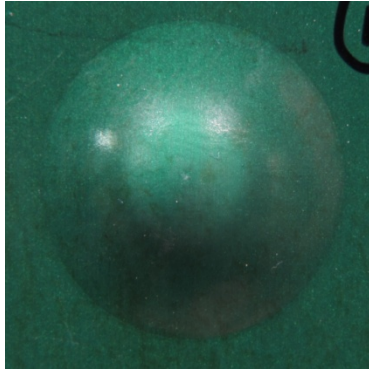
Hydraulic Fluid: 70°C, 189 hrs



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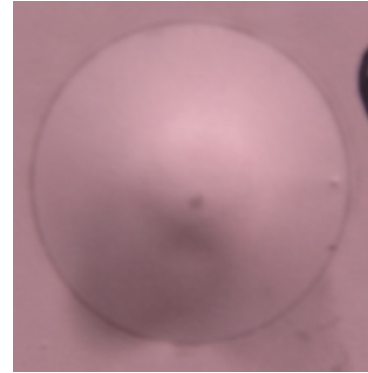
Impact damage resistance

Panel Type B

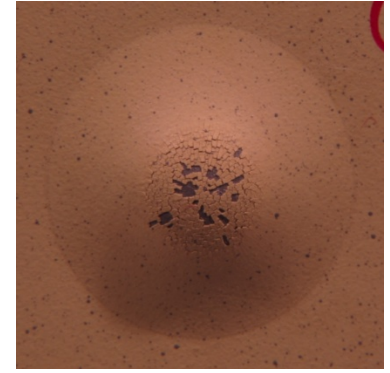


Rockhard

Panel Type C

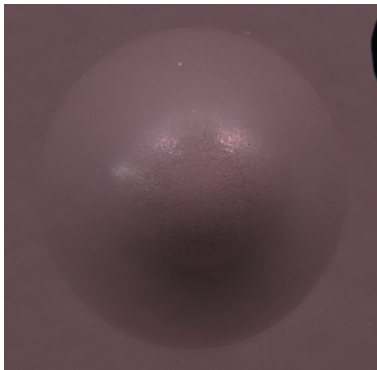


Rockhard

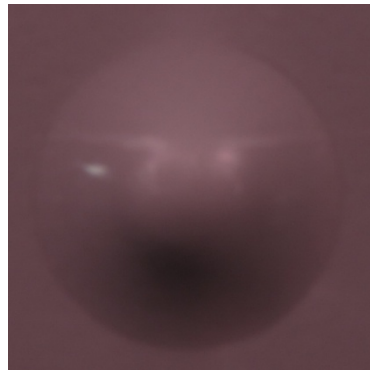


Legacy

Panel Type D



Rockhard



Legacy

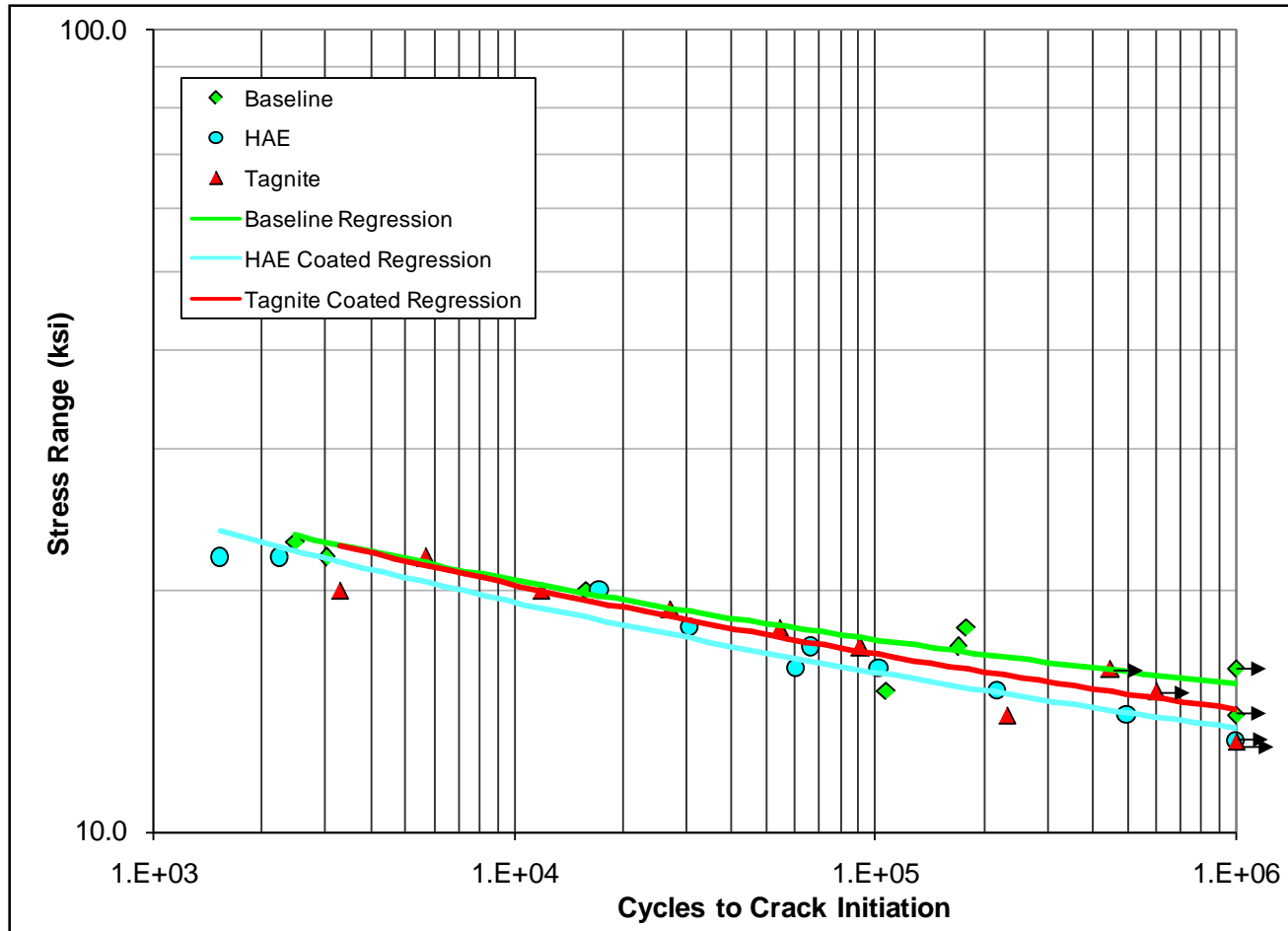
Criteria: There shall be no cracking or detachment at an indentation depth of 3.8 mm (.15 inch) using a 1000±1 g punch AND the new coating system shall meet or exceed the performance of the old coating configuration.

Result: Pass



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Fatigue performance



Criteria:

No increase in fatigue debit over legacy or baseline coating.

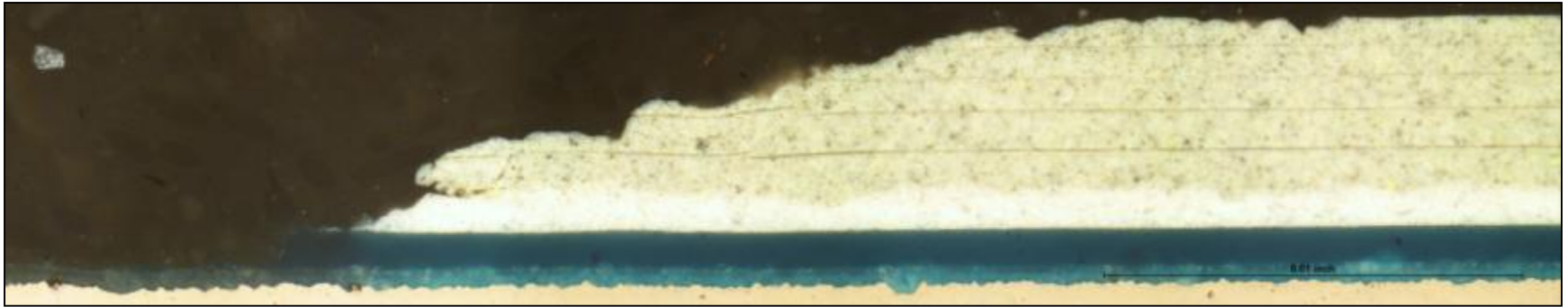
Result: Pass



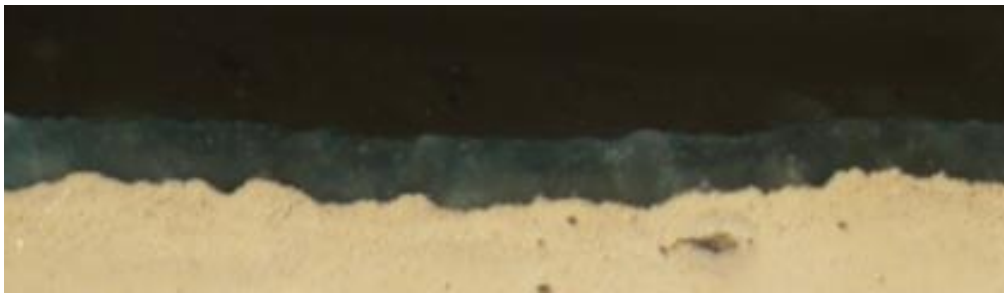
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Repair and Overhaul

- Plastic Media Blast removal process successful in removing the paint without removing the anodize



Cross section of a painted panel partially stripped via plastic media blasting



Higher magnification view of the remaining conversion coating

Criteria: *The coating shall be strippable and be capable of supporting subsequent re-paint*

Results: PASSES



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Engine Test

- Purpose
 - Assembly/fit check
 - Leak check
- Testing details
 - Prop Stand test
 - Post-engine test inspection
- Results
 - After 3 tear downs and 150 hours
 - New coating configuration PASSES

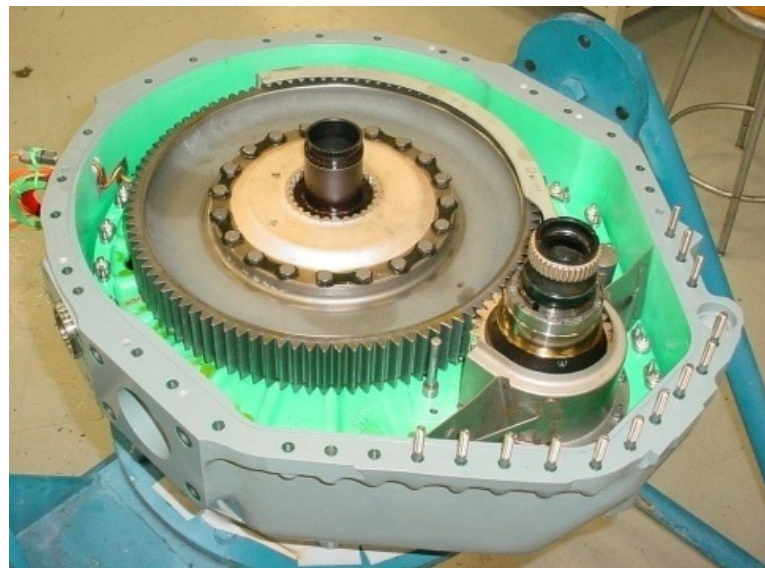


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Conclusion:

It's in production!

- Performance improvement
- Environmental liability eliminated
- Unit Cost neutral
- Improvement in Aftermarket costs



Ref 1: <http://www.magnesium-elektron.com/about-magnesium.asp?ID=1>

Ref 2: www.intlmag.org/showcase/mg001.pdf

Ref 3: <http://vwparts.aircooled.net/OEM-VW-Magnesium-Engine-Case-043-101-025OE-p/oem-vw-engine-case.htm>

Ref 4: <http://www.fwtec.com/FW/nanosolution.html#>

Ref 5: Rolls-Royce Front Frame example

Ref 6: <http://www.volksworld.com/blog/staff-blogs/jons-blog/stripping-down-a-donor-beetle-engine/>

Ref 7: http://www.corrosionist.com/galvanic_corrosion_chart.htm

Ref 8: <http://airandspace.si.edu/webimages/highres/5013h.jpg>

Ref 9: Corrosion and Materials, Vol 30 No 6, 2

December 2005 ISSN 1326-193

Ref 10 <http://www.arl.army.mil/www/default.cfm?page=375>



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Questions?

Ref 1: <http://www.magnesium-elektron.com/about-magnesium.asp?ID=1>
Ref 2: www.intlmag.org/showcase/mg001.pdf
Ref 3: <http://vwparts.aircooled.net/OEM-VW-Magnesium-Engine-Case-043-101-025OE-p/oem-vw-engine-case.htm>
Ref 4: <http://www.fwtec.com/FW/nanosolution.html#>
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Ref 10 <http://www.arl.army.mil/www/default.cfm?page=375>



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